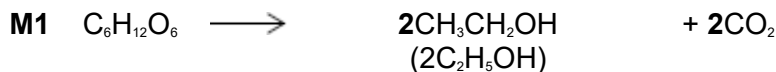


**M1.(a)**



*Penalise C<sub>2</sub>H<sub>6</sub>O for ethanol in M1.*

**M2 and M3**

*Mark M2 and M3 independently.*

Any **two** conditions **in any order** for **M2** and **M3** from

- (enzymes from) yeast or zymase
- 25 °C ≤ T ≤ 42 °C OR 298 K ≤ T ≤ 315 K
- anaerobic / no oxygen / no air OR neutral pH

*A lack of oxygen can mean either without oxygen or not having enough oxygen and does not ensure no oxygen, therefore only credit "lack of oxygen" if it is qualified.*

*Penalise 'bacteria', 'phosphoric acid', 'high pressure' using the list principle.*

**M4** (fractional) distillation or GLC

*Ignore reference to 'aqueous' or 'water' (ie not part of the list principle).*

**M5** Carbon-neutral **in this context** means

There is no net / overall (annual) carbon dioxide / CO<sub>2</sub> emission to the atmosphere

**OR**

There is no change in the total amount / level of carbon dioxide / CO<sub>2</sub> present in the atmosphere

*For M5 – must be about CO<sub>2</sub> and the atmosphere.*

*The idea that the carbon dioxide / CO<sub>2</sub> given out equals the carbon dioxide / CO<sub>2</sub> that was taken in from the atmosphere.*

5

(b) **M1**  $q = m c \Delta T$  (this mark for correct mathematical formula)

*Full marks for M1, M2 and M3 for the correct answer.*

*In M1, do not penalise incorrect cases in the formula.*

$$\text{M2} = (75 \times 4.18 \times 5.5)$$

$$1724 \text{ (J) OR } 1.724 \text{ (kJ) OR } 1.72 \text{ (kJ) OR } 1.7 \text{ (kJ)}$$

(also scores **M1**)

*Ignore incorrect units in **M2**.*

**M3** Using 0.0024 mol

therefore  $\Delta H = \underline{-718}$  (kJ mol<sup>-1</sup>)

(Accept a range from -708 to -719 but do not penalise more than 3 significant figures)

*Penalise **M3** ONLY if correct numerical answer but sign is incorrect. Therefore **+718** gains two marks.*

*If units are quoted in **M3** they must be correct.*

*If  $\Delta T = 278.5$ , CE for the calculation and penalise **M2** and **M3**.*

**M4** and **M5** in any order

Any **two** from

- incomplete combustion
- heat loss
- heat capacity of Cu not included
- some ethanol lost by evaporation
- not all of the ( $2.40 \times 10^{-3}$  mol) ethanol is burned / reaction is incomplete  
*If  $c = 4.81$  (leads to 1984) penalise **M2** ONLY and mark on for **M3** = - 827*

5

- (c) (i) **M1** enthalpy / heat / energy change (at constant pressure) or enthalpy / heat / energy needed in breaking / dissociating (a) covalent bond(s)  
*Ignore bond making.*

**M2** averaged for that type of bond over different / a range of molecules / compounds

*Ignore reference to moles.*

2

- (ii) **M1**

$$\underline{\sum B(\text{reactants}) - \sum B(\text{products}) = \Delta H}$$

**OR**

$$\underline{\text{Sum of bonds broken} - \text{Sum of bonds formed} = \Delta H}$$

**OR**

$$B(C-C) + B(C-O) + B(O-H) + 5B(C-H) + 3B(O=O) - 4B(C=O) - 6B(O-H) = \Delta H = -1279$$

Correct answer gains full marks.

Credit **1 mark for - 496** (kJ mol<sup>-1</sup>)

For other incorrect or incomplete answers, proceed as follows

- check for an arithmetic error (AE), which is either a transposition error or an incorrect multiplication; this would score 2 marks (**M1** and **M2**).

If no AE, check for a correct method; this requires either a correct cycle with 2CO<sub>2</sub> and 3H<sub>2</sub>O OR a clear statement of **M1** which could be in words and scores **only M1**.

**M2** (also scores **M1**)

$$348+360+463+5(412)+ 3B(O=O)$$

$$\begin{array}{l} (3231) \qquad \qquad \qquad \text{(or } 2768 \text{ if O-H cancelled)} \\ - 4(805) - 6(463) = \Delta H = - 1279 \end{array}$$

$$(5998) \qquad \qquad \qquad \text{(or } 5535 \text{ if O-H cancelled)}$$

$$3B(O=O) = \underline{1488} \text{ (kJ mol}^{-1}\text{)}$$

Credit a maximum of one mark if the only scoring point is bonds formed adds up to **5998 (or 5535)** OR bonds broken includes the calculated value of **3231 (or 2768)**.

**M3**

$$B(O=O) = \underline{496} \text{ (kJ mol}^{-1}\text{)}$$

Award 1 mark for -496

**Students may use a cycle and gain full marks**

3

[15]

- M2.(a)** (i) M1 c(oncentrated) phosphoric acid / c(onc.) H<sub>3</sub>PO<sub>4</sub>  
**OR** c(oncentrated) sulfuric acid / c(onc.) H<sub>2</sub>SO<sub>4</sub>

*In M1, the acid must be concentrated.*

*Ignore an incorrect attempt at the correct formula that is written in addition to the correct name.*

M2 Re-circulate / re-cycle the (unreacted) ethene (and steam) / the reactants

**OR** pass the gases over the catalyst several / many times

*In M2, ignore "remove the ethanol".*

*Credit "re-use".*

2

- (ii) M1  
(By Le Chatelier's principle) the equilibrium is driven / shifts / moves to the right / L to R / forwards / in the forward direction

**M2 depends on a correct statement of M1**

The equilibrium moves / shifts to

- oppose the addition of / increased concentration of / increased moles / increased amount of water / steam
- to decrease the amount of steam / water

**Mark M3 independently**

M3 Yield of product / conversion increase **OR** ethanol increases / goes up / gets more

3

- (iii) M1 Poly(ethene) / polyethene / polythene / HDPE / LDPE

**M2 At higher pressures**

More / higher cost of electrical energy to pump / pumping cost

**OR**

Cost of higher pressure equipment / valves / gaskets / piping etc.

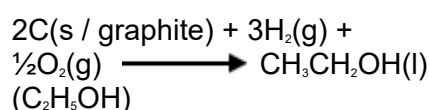
**OR** expensive equipment

*Credit all converse arguments for M2*

2

- (b) M1 for balanced equation

M2 for state symbols in a correctly balanced equation



*Not multiples but credit correct state symbols in a correctly balanced equation.*

*Penalise C<sub>2</sub>H<sub>6</sub>O but credit correct state symbols in a correctly balanced equation.*

2

- (c) (i) M1 The enthalpy change / heat change at constant pressure when 1 mol of a compound / substance / element

*If standard enthalpy of formation **CE=0***

M2 is burned / combusts / reacts completely in oxygen

**OR** burned / combusted / reacted in excess oxygen

M3 with (all) reactants and products / (all) substances in standard / specified states

**OR** (all) reactants and products / (all) substances in normal states under standard conditions / 100 kPa / 1 bar and specified T / 298 K

For **M3**  
Ignore reference to 1 atmosphere

3

(ii) M1

Correct answer gains full marks

$$\underline{\Sigma B(\text{reactants}) - \Sigma B(\text{products}) = \Delta H}$$

Credit 1 mark for (+) 1279 (kJ mol<sup>-1</sup>)

OR

$$\underline{\text{Sum of bonds broken} - \text{Sum of bonds formed} = \Delta H}$$

OR

$$B(\text{C-C}) + B(\text{C-O}) + B(\text{O-H}) + 5B(\text{C-H}) + 3B(\text{O=O}) \text{ (LHS)} \\ - 4B(\text{C=O}) - 6B(\text{O-H}) \text{ (RHS)} = \underline{\Delta H}$$

M2 (also scores **M1**)

$$348+360+463+5(412)+3(496) \text{ [LHS = 4719]} \\ (2060) \quad (1488)$$

$$- 4(805) - 6(463) \text{ [RHS = - 5998]} = \Delta H \\ (3220) \quad (2778)$$

OR using only bonds broken and formed (**4256 - 5535**)

For other incorrect or incomplete answers, proceed as follows

- check for an arithmetic error (AE), which is either a transposition error or an incorrect multiplication; this would score 2 marks (**M1** and **M2**)
- If no AE, check for a correct method; this requires either a correct cycle with 2C and 6H and 7O OR a clear statement of **M1** which could be in words and scores **only M1**

M3

$$\Delta H = \underline{- 1279} \text{ (kJ mol}^{-1}\text{)}$$

Allow a maximum of one mark if the only scoring point is  
LHS = 4719 OR RHS = 5998

Award 1 mark for +1279

**Candidates may use a cycle and gain full marks**

3

(d) (i) Reducing agent OR reductant OR electron donor  
OR to reduce the copper oxide

Not "reduction".

Not "oxidation".

Not "electron pair donor".

1

(ii) CH<sub>3</sub>COOH

1  
[17]

**M3.(a)** (Enthalpy change to) break the bond in 1 mol of chlorine (molecules)

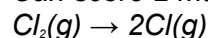
*Allow (enthalpy change to) convert 1 mol of chlorine molecules into atoms*

*Do not allow energy or heat instead of enthalpy, allow heat energy*

1

To form (2 mol of) gaseous chlorine atoms / free radicals

*Can score 2 marks for 'Enthalpy change for the reaction':*



*Equation alone gains M2 only*

*Can only score M2 if 1 mol of chlorine molecules used in M1 (otherwise it would be confused with atomisation enthalpy)*

*Any mention of ions, CE = 0*

1

(b) (For atomisation) only 1 mol of chlorine atoms, not 2 mol (as in bond enthalpy) is formed / equation showing ½ mol chlorine giving 1 mol of atoms

*Allow breaking of one bond gives two atoms*

*Allow the idea that atomisation involves formation of 1 mol of atoms not 2 mol*

*Allow the idea that atomisation of chlorine involves half the amount of molecules of chlorine as does dissociation*

*Any mention of ions, CE = 0*

1

(c) (i)  $\frac{1}{2}\text{F}_2(\text{g}) + \frac{1}{2}\text{Cl}_2(\text{g}) \rightarrow \text{ClF}(\text{g})$

1

(ii)  $\Delta H = \frac{1}{2}E(\text{F}-\text{F}) + \frac{1}{2}E(\text{Cl}-\text{Cl}) - E(\text{Cl}-\text{F})$

*Allow correct cycle*

1

$$E(\text{Cl-F}) = \frac{1}{2}E(\text{F-F}) + \frac{1}{2}E(\text{Cl-Cl}) - \Delta H$$

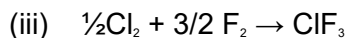
$$= 79 + 121 - (-56)$$

$$= 256 \text{ (kJ mol}^{-1}\text{)}$$

*-256 scores zero*

*Ignore units even if wrong*

1



*If equation is doubled CE=0 unless correct answer gained by / 2 at end*

*This would score M1*

1

$$\Delta H = \frac{1}{2} E(\text{Cl-Cl}) + \frac{3}{2} E(\text{F-F}) - 3E(\text{Cl-F})$$

$$= 121 + 237 - 768 \text{ / (or } 3 \times \text{ value from (c)(ii))}$$

*This also scores M1 (note = 358 - 768)*

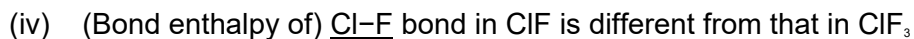
1

$$= -410 \text{ (kJ mol}^{-1}\text{)}$$

*If given value of 223 used ans = -311*

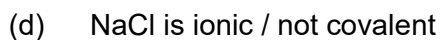
*Allow 1 / 3 for +410 and +311*

1



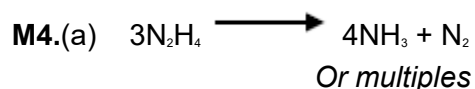
*Allow Cl-F bond (enthalpy) is different in different compounds (QoL)*

1



1

[11]



- (b) M1 enthalpy / heat (energy) change / required / needed to break / dissociate a covalent bond (or a specified covalent bond)

*Ignore bond making*

*Ignore standard conditions*

**M2 requires an attempt at M1**

M2 average / mean over different molecules / compounds / substances

- (c) M1  
 $\sum (\text{bonds broken}) - \sum (\text{bonds formed}) = \Delta H$

**M1 could stand alone**

**OR**

Sum of bonds broken – Sum of bonds formed =  $\Delta H$

Award full marks for correct answer

M2 (also scores **M1**)

*Ignore units*

$4(+388) + 163 + 2(146) + 4(463) - 944 - 8(463) = \Delta H$

OR broken +3859 (2007) formed – 4648 (2796)

M3

$\Delta H = \underline{-789}$  (kJ mol<sup>-1</sup>)

*Two marks can score with an arithmetic error in the working*

Award 1 mark for + 789

**Credit one mark only** for calculating either the sum of the bonds broken or the sum of the bonds formed provided this is the only mark that is to be awarded

Students may use a cycle and gain full marks